Mercury System Specification

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System Overview

This document is the primary technical reference for the Mercury Satellite Internet Terminal hardware platform from WebTV Networks, Inc. The key product features are as follows:

- 250-MHz QED RM5231 CPU
- 32-MB SDRAM (64 bits, 83MHz)
- SOLO2.1 ASIC with integrated MPEG-2 decoder
- Fud2 ASIC with integrated PCI bridge and satellite transport stream decoder
- 30-GB hard disk drive for 4-hour digital video recording (DVR)
- 2-MB boot ROM
- Soft modem with DAA line interface
- Dual satellite tuners with forward error correction (FEC) and quaternary phase-shift keying (QPSK) demodulation
- RF Modulator
- Front panel AV connectors
- Real panel AV connectors
- S/PDIF optical audio output
- Two USB ports (only one port may be used at a time)
- Two Smart Card slots (conditional access and WebTV)
- Parallel port
- IR in and out
- Front panel controls (7 buttons)
- AC3 audio decoding and downmixing
- TV picture-in-picture (PIP), using either tuner
- TV pause plus (ffwd, skip, rewind)
- DVR 1.0 (one-touch record)

The system architecture is centered around the SOLO2 custom ASIC. SOLO2 is coupled to the following devices:

- General-purpose RISC processor—provides the core computation
- Fud2 PCI bridge and transport stream decoder IC—provides the PCI interface to the USB ports
- High-speed memory—provides the graphics generation resources

The board contains two digital satellite tuners, which allows subscribers to simultaneously receive two digital satellite TV channels. These tuners perform FEC/QPSK on the received digital data and provide two MPEG-2 transport streams to the Fud2 ASIC. The tuners allow the flexibility to display picture-in-picture (PIP). The video can be processed and sent out over the system's video and audio connectors for TV viewing or digital video recording (DVR) to hard disk.

Code storage is provided by a ROM subsystem and a hard disk drive, which is also used for transitory data storage and DVR. Data communication is provided by a software modem using a simple CODEC (Coder/Decoder) and a DAA (Direct Access Arrangement). Internet access is through the modem.

The ROMs on the system board contain the bootstrap code, which brings the system up to the point where a user can access the cable modem and see a display on the television. The hard disk drive contains the browser software needed for accessing web pages. The disk contents are updated periodically over the phone lines as new software becomes available.

The Mercury Internet Terminal is shown in Figure 1-1.

Figure 1-1 Mercury Internet Terminal

1.1 Satellite TV Concepts

Recently, satellite operators have been able to expand their service offerings with high-quality encoding and data broadcasting products.

The digital broadcast industry has entered an era of ever-intensifying competition for the home entertainment consumer. Competition is vigorous and new technologies will create even greater competition for consumer dollars. Making the commitment to launch digital data and TV broadcasts is a decision to grow business by bringing a new level of products and services to customers. There is a great need to economically offer more new services, address competition, and lay the foundation for lucrative new revenue streams and increased profitability.

Providing satellite digital television broadcasting helps headends in responding to growing demand for a wider and deeper range of multimedia services and value-added features.

Digital satellite broadcast equipment uses powerful digital compression technology to squeeze as many as 12 digitally-encoded video services into the space of a single 6 MHz analog TV channel. Satellite broadcast systems are able to uplink digitized, compressed, and encrypted programming in MPEG-2 format. The signals can be received with consumer satellite equipment, which decrypts and demodulates the information for delivery to the TV set. The result is richer and clearer pictures and sound than ever before experienced on regular analog cable or broadcast television.

1.1.1 DBS

A new class of television services have recently become available to viewers in the continental United States. These services allow households to receive television programming directly from satellites on small (18 inch to 3 foot diameter) satellite dishes that are not movable, but instead are aimed at one position in the sky.

The signals are digitally compressed, allowing several programs to be broadcast from a single satellite transponder thereby allowing up to 200 channels receivable with a dish pointed at one orbital position in the sky. Programming on the various services includes most major cable services, sports, Pay Per View (PPV) movies, audio services, and specialized “niche” programming aimed at smaller audiences. These services are often referred to as Direct To Home (DTH) services but the term Direct Broadcast Satellite (DBS) services is more generally used.

There are currently four DBS services in operation with others expected to begin in the coming months. Although they still have far fewer subscribers than the Cable TV industry, DBS services are rapidly adding subscribers and the industry has very strong growth potential. As a result, many companies are interested in getting into the DBS business.

DirecTV™ (a subsidiary of Hughes Communications) operates from specially designed High Powered DBS satellites, whose signals are receivable with 18-inch dishes. The DirecTV service was the first High Powered DBS service and is considered the premier DBS service in the U.S.

DBS programming is sent up to a satellite orbiting 22,300 miles above the equator. The satellite's orbit is set to match the speed and direction of the Earth's surface, so it appears to be stationary when viewed from Earth. This type of satellite is referred to as geostationary or geosynchronous. It is this "stationary" orbit that allows fixed dishes to continuously receive the satellite's signal. There are nearly 40 satellites currently in this type of orbit over North America, and well over 100 around the globe. The DBS signal is gathered from a number of sources and uplinked to the satellites from the modern facilities of satellite broadcast providers.

The DBS programming, received by the satellite, is processed and then sent back down to the Earth in a very broad beam of radio waves. Because the signal beamed down to the Earth is so widely dispersed, residences from Seattle, Washington, to Key West, Florida, and San Diego, California, to Bangor, Maine, can enjoy the benefits of DBS with the same equipment -- an 18-inch dish and the WebTV Mercury Satellite Internet Terminal.

A DBS service transmits a bitstream that contains compressed audio, compressed video, authorization information, program guide information, and other information. The Mercury receiver in each subscriber's home decodes the digital bitstream, converting it into video and audio that can be displayed by conventional TV sets. Each service requires a decoder designed to work with its system.

The DirecTV service uses three specially designed High Power Ku-band satellites that operate from fixed positions in the sky. The first (DBS1) uses sixteen 120-watt transponders while the other two (DBS2 and DBS3) are configured to each use eight 240-watt transponders. This results in a total of 32 broadcast transponders. DirecTV has sold five of the 120-watt transponders to USSB. (Actually USSB owns 5/16 of one of the entire satellites since federal regulations require DBS broadcasters to own their broadcast facilities.) The two competing companies both offer programming receivable with a common dish and decoder.

The hardware used by DirecTV and USSB is called the Digital Satellite System or DSS™. The WebTV Mercury Internet Terminal is a DSS-compatible receiver.

1.1.2 Conditional Access

The Mercury system accepts a credit-card sized processor board called a SmartCard. SmartCard plugs into the front bezel and allows the built-in decoder to receive authorized programming. An authorization stream is sent on each transponder, along with the video and audio information. The SmartCard can be inexpensively and easily replaced by the owner if necessary to help curb piracy.

1.1.3 Signalling and Encoding

The following steps are taken before sending data out to a satellite link for distribution:

1. The contents are randomized to minimize noise.
2. Reed-Solomon Forward Error-Correction (FEC), a block coding technique, adds redundant error protection information to the packet data. This is a very efficient system that adds only around 8% overhead to the signal. It is called the Outer Code.
3. Convolutional Interleaving is then applied to the packet contents.
4. A further error-correction system is added, using a punctured Convolutional Code. This second error-correction system, the Inner Code, can be adjusted, in terms of the amount of overhead, to suit the needs of the service provider.
5. The signal is then used to modulate the satellite broadcast carrier using quadrature phase-shift keying (QPSK).

The audio in the QPSK signal is MPEG-1 Layer II encoded. Surround sound can be achieved by encoding the audio with Dolby Pro-Logic before MPEG encoding. The video is encoded using MPEG-2 syntax with up to CCIR 601-1 sampling rates, which is capable of up to 720 x 480 images, although lower resolutions are currently being used.

The system uses a statistical multi-program encoder called a StatMux that dynamically varies the bit rate according to video content, taking into consideration other programs multiplexed on the same transponder.

Each of the DBS satellites can be configured for either sixteen 120 Watt transmissions or eight transmissions of 240 Watts each, based on the DC power-generating capability of satellite’s solar panels.

The DSS architecture can broadcast 40 Mbits/sec per transponder in either of two error control modes. In High mode, 30 Mbps is allocated to information and 10 Mbps to error control. In Low mode, 23 Mbps is allocated to information and 17 Mbps is allocated to error control. High mode requires about 3dB more signal power to achieve an end- to-end availability equivalent to Low mode.

DBS-1 runs in Low mode, while DBS-2 and DBS-3 run in High mode. Therefore DirecTV and USSB have 16 transponders at 240 Watts in High mode and 16 at 120 Watts in Low mode.

1.1.4 Standards

DSS makes use of several standards, but is not fully compliant with the European Digital Video Broadcasting (DVB) satellite convention because DSS was designed before the ratification of DVB. However, DSS should be compliant with the most difficult interoperability aspect of DVB, which is video and audio representation. In fact, the video and audio bitstreams are unaffected by the transport layer protocol. An MPEG-2 video bitstream transported over DSS packets demultiplexes identically to a bitstream transported by DVB means.

DVB specifies conformance at several levels, including the following:

- Channel Coding—for example, symbolic rate, QPSK modulation, Reed-Solomon forward error correction, Viterbi convolution for outer error correction, and packet interleaving
- Transport Layer —MPEG-2 Systems Transport bitstreams
- Elementary Stream Layers—MPEG-2 Video and MPEG-1 Audio

DSS elements are nearly identical to DVB. Subtle differences exist, such as packet length (DSS packets are 147 bytes long whereas MPEG-2 Transport stream packets are 188 bytes long), but the more expensive implementation items are the same (modulation and error correction).

The DVB document also defines cable (64 QAM) and terrestrial broadcasting (QAM/ OFDM) conventions.

1.1.5 General Block Diagram

To illustrate the makeup of the DSS System, a typical block diagram of the video signal path is provided in Figure 1-2.

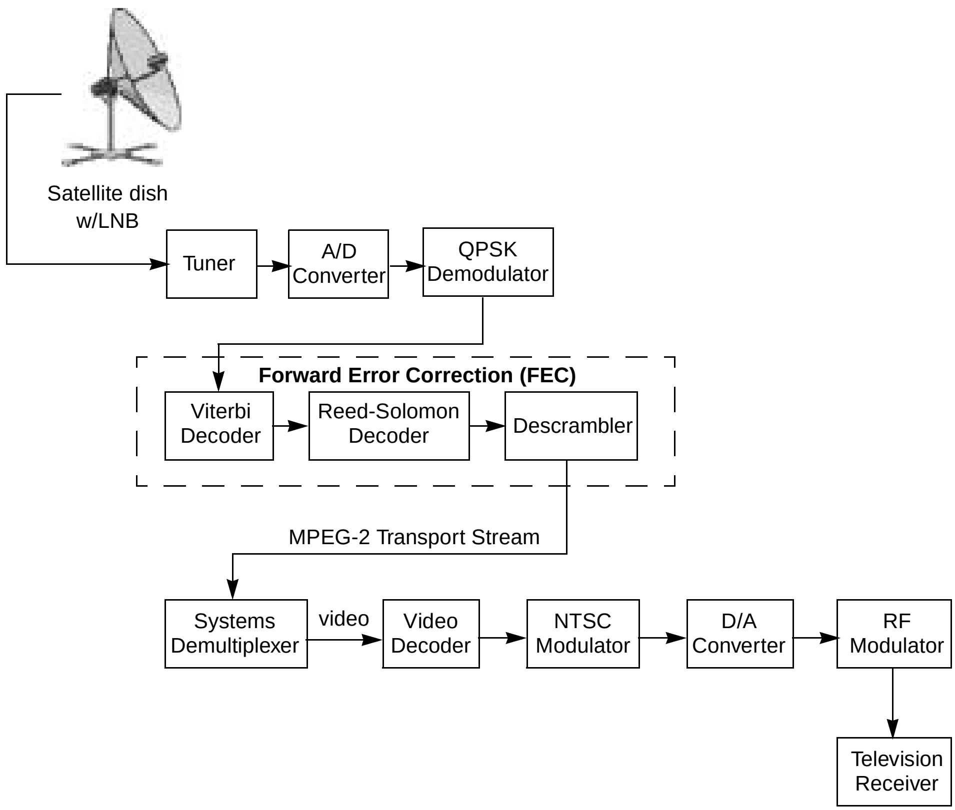

Figure 1-2 DSS Signal Path Block Diagram

Below is a brief explanation of the functions of each of the blocks:

- Dish LNB—LNB is an acronym for Low-Noise Block down-converter, which typically mounts right onto the satellite dish. Low-noise refers to the amount of electrical signal noise added by the LNB to a received satellite signal. With lower added noise, the overall signal recovery of the system is improved. LNBs manufactured for the Ku satellite broadcast band are in the 10.95 GHz to 12.7 GHz range. An LNB is used to convert the 12-GHz satellite signal to more usable frequencies in the L-band (950 to 2150 MHz) range. This conversion lowers the cost of the processing electronics by eliminating complex and expensive microwave

components. These lower frequencies are more easily handled by commercially available components used in other electronic applications.

- Tuner—modern integrated circuit satellite tuners directly tune L-band signals to baseband using a broadband I/Q (in-phase/quadrature-phase) down-converter. The operating frequency range spans from at least 950MHz to 2150MHz. The down-converted signal must be modulated below the L-Band signal into the 50- to 700-MHz range. This is the range of VHF/UHF and CATV. The tuner usually includes a low-noise amplifier (LNA) with automatic gain control (AGC), two down-converter mixers, an oscillator buffer with 90° quadrature generator and prescaler, and baseband amplifiers. The tuner normally has an automatic gain control (AGC) range of around 40 or 50dB, allowing input power levels as low as approximately -69dBm.
- A/D Converter—samples the analog baseband signal for processing by the QPSK demodulator. The A/D converter digitizes the incoming I (in-phase) and Q (quadrature) signals into an internal digital representation (usually 6 bits or so) for processing by the QPSK demodulator.
- QPSK Demodulator—converts the sampled modulated signal into two streams (I and Q) of discrete bits
- Forward Error Correction (FEC)—improves the capacity of a channel by adding some carefully designed redundant information to the data being transmitted through the channel. The process of adding this redundant information is known as channel coding. If errors are detected during a one-way satellite video transmission, it is not possible for the receiving equipment to respond with a request for transmission. Therefore, error coding must be built into the transmitted satellite data so that the equipment at the receiving end can detect errors and use the error coding data to make corrections as needed. The power of FEC is that the system can, without retransmissions, find and correct limited errors caused by a transport or storage system. A typical FEC subsystem consists of a Viterbi Decoder, Reed-Solomon Decoder, and Descrambler.

  Viterbi Decoder—convolutional encoding with Viterbi decoding is an FEC technique that is particularly suited to a channel in which the transmitted signal is corrupted mainly by additive white gaussian noise. Convolutional codes operate on serial data, one bit (or a few bits) at a time. Viterbi decoding performs deconvolution of the bitstream.

  Reed-Solomon Decoder—in contrast to convolutional encoding, Reed-Solomon encoding is a block-coding technique that processes the data in batches, or blocks, rather than a bit at a time. It provides for correcting random errors or bursts of errors. A Reed-Solomon encoder supplies redundant bits with each block of data that the corresponding decoder at the other end uses to detect and correct errors.

  Descrambler—descrambles the data that was originally randomized for the purpose of more evenly distributing electrical noise.

- Systems Demultiplexer—separates audio, video, VBI (vertical blanking information: data such as closed caption and teletext), program guide, and conditional access information into separate bitstreams
- Video Decoder—decodes video bitstreams into raw 4:2:0 YCbCr pictures. These pictures (whether coded as fields or frames) are output, one field at a time, at a sample rate of 13.5 MHz for Y (luminance) and 6.75 MHz for each of the color channels (Cb and Cr).
- NTSC Modulator—converts the “CCIR 601” YCbCr format stream into a composite video stream.
- D/A Converter—separately converts the composite digital video stream and component Y/C digital video stream into analog baseband signals. The Y/C signal is compatible with the S-video format conveyed on the round, mini-DIN 4-pin connector. The composite analog signal is additionally provided on the RCA phono-style connector. The video composite signal is also modulated on an RF carrier.
- RF Modulator—modulates the analog composite video signal onto an RF carrier (channel 3 or 4), along with a (mono) analog audio subcarrier.

1.2 Mercury Architecture

Figure 1-3 is a simplified Mercury block diagram.

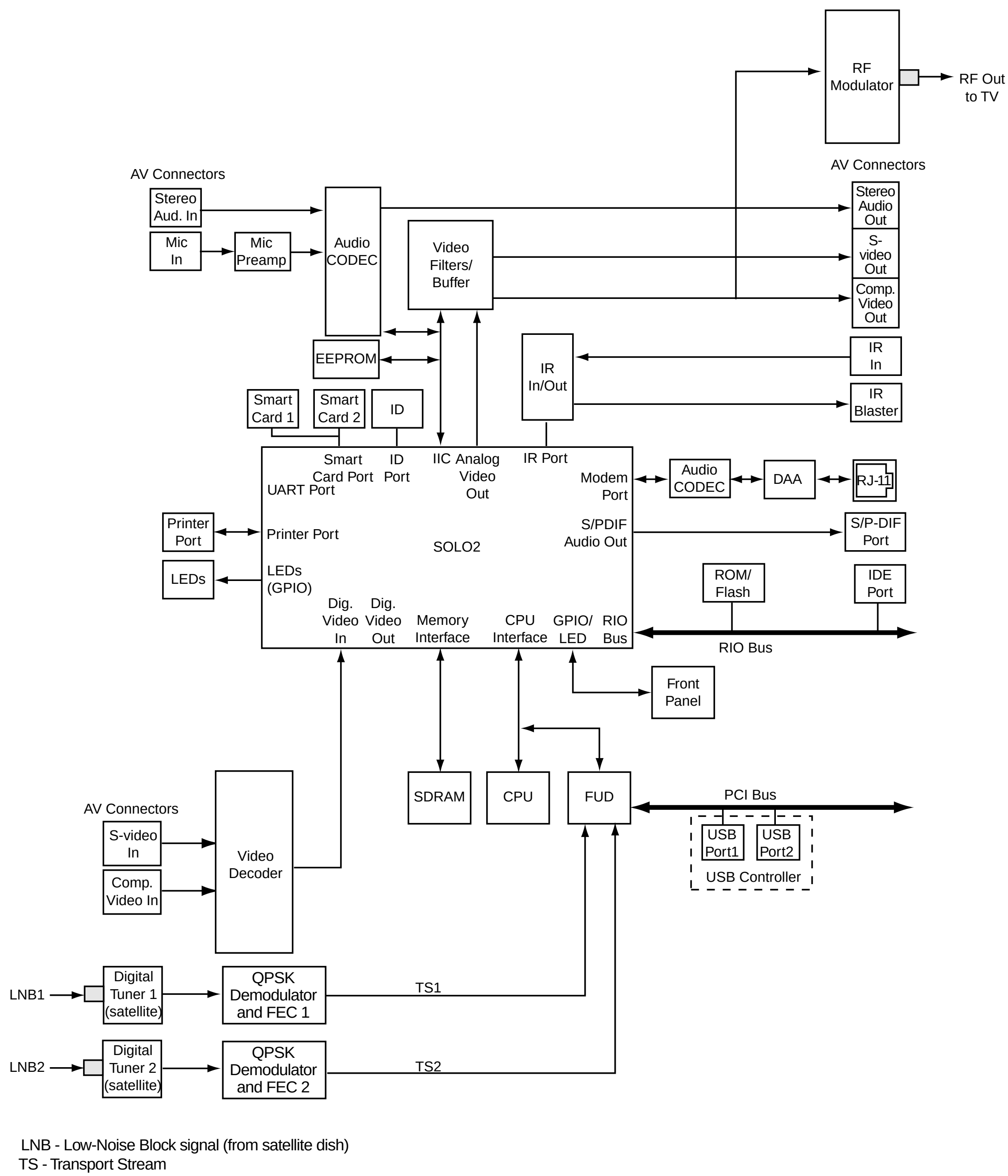

Figure 1-3 Mercury Architecture

1.3 Principal Board Components

The primary board components and subsystems on Mercury are:

- Satellite Tuner/Demodulator/FEC 1
- Satellite Tuner/Demodulator/FEC 2
- RF Modulator
- Fud2 ASIC
- SOLO2 ASIC
- RISC CPU
- Memory (SDRAM, ROM, EEPROM)
- CODEC and DAA for soft modem
- Video Subsystem ICs
- Audio Subsystem ICs
- ID Chip
- Smart Card Interface
- USB Interface
- Clock Generator

1.4 External Interfaces

This section provides a brief summary of the Mercury I/O interfaces. More information can be found in Chapter 2, “Functional Description.”

1.4.1 Composite Video Input

Composite NTSC video (PAL input is not supported) input is accepted on two different RCA-type pin jacks, one at the rear panel, and one at the front panel. System software selects which input is processed. The nominal level is 1V p-p.

1.4.2 Composite Video Output

Composite NTSC or PAL video output is provided on two RCA-type pin jacks at the rear panel. The nominal level is 1V p-p.

1.4.3 S-Video Input

Standard S-Video (Y/C) input is provided via a standard 4-pin mini-DIN connector on the rear panel. The input level is 1.0V p-p for both Y and C signals.

1.4.4 S-Video Output

Standard S-Video (Y/C) output is provided via a standard 4-pin mini-DIN connector on the rear panel. The output level is 1V p-p.

1.4.5 Digital Video Interface

Digitized analog video is provided to the SOLO2 ASIC DIV[7:0] inputs from the BT835 video decoder.

1.4.6 L & R Audio Inputs

Left and Right line-level audio inputs are accepted via two pairs of RCA-type pin jacks, one pair at the rear panel and one pair at the front of the unit. For the rear panel audio inputs, system software selects either Right and Left audio in or microphone in. System software also chooses whether to process the rear panel audio inputs or the front panel audio inputs. The Left and Right audio inputs can accept up to 1V RMS without clipping.

1.4.7 L/Mono and R Analog Audio Outputs

Left and right audio outputs are available at two pairs of RCA-type pin connectors at the rear panel. Stereo sound is output if both connectors at the back panel are used. If only the left connector is used, monaural audio (the sum of the left and right audio outputs) is available on the left connector at both the rear and front panels.

1.4.8 Microphone Input

Microphone input is accepted via a 3.5mm diameter miniature phono jack. The input level is 20mV RMS maximum. System software selects between microphone and audio inputs.

1.4.9 RF Input

Two digital RF inputs from the satellite tuners are accommodated by two separate F-type connectors.

1.4.10 RF Output

One F-type connector from the RF modulator is provided for local (channel 3 or 4) RF output.

1.4.11 USB Interface

Two stacked 4-pin USB connectors are provided on the board. The USB ports are controlled through a single 82C861 dual-port PCI-to-USB bridge.

Caution: The system power supply is rated for 2.5A @ +5v, max. Attaching two USB devices that exceed this limit may overload the power supply.

1.4.12 S/PDIF Digital Audio Output

Optical S/PDIF (Sony/Philips Digital Interface Format) audio is provided on a connector at the rear panel of the board.

1.4.13 Parallel Port

An IEEE-1284 standard, bidirectional parallel port is provided on a female 25-pin subminiature D-type connector.

1.4.14 UART Port

An EIA/TIA-562 UART port is provided on a male 9-pin subminiature D-type connector.

1.4.15 IR Emitter Output

Drive for an external IR emitter is provided via a 3.5mm diameter miniature phono jack.

1.4.16 Telephone Line

Connection to a phone line is made with a standard RJ-11 telephone jack. The telephone interface complies with FCC Rules Part 68 and Canadian DOC CE-03 regulations.

1.4.17 LEDs

1.4.17.1 General-Purpose LEDs

Three LEDs are mounted on the board so that they illuminate light pipes mounted in the front bezel. The LEDs indicate the following:

- Green: Power Indication

  If the POWER button is pressed when the power is off, the system powers up and the LED is illuminated

  If the POWER button is pressed when the system is powered up, the unit starts to shut down and the LED blinks until the disk is parked

  If the POWER button is pressed when the system is shutting down (green light is blinking), there is no action

- Yellow: Connected Indication

  LED is on steady when the system is connected to the WebTV server via phone line

  LED is off when the system is not connected

  LED blinks when the system is in the process of connecting or is receiving or sending data

- Red: Message Indicator

  A steady on LED when no user is logged in indicates that unread messages are available in any of the system's accounts

  A steady on LED with a user logged in indicates that unread messages are available in that user's account

  When the LED is off with no user logged in, no new messages are available for any account on the system

  When the LED is off with a user logged in, there no new messages for that user

The front panel also contains a blue LED, which, when illuminated, indicates that digital video is being recorded to disk.

1.4.18 Front Panel

The front panel contains the following pushbuttons:

- POWER—a switch that turns the system power on and off. The switch is illuminated (green) when power is on.
- GUIDE—pressing this switch takes the user to TV listings for the current date and time from any TV World screen. Additional presses of the GUIDE button cycles through lists of favorite channels
- HOME—pressing this switch takes the user to TV Home screen (equivalent of main menu) when in TV World, and Web Home when in Web World
- LEFT, RIGHT, UP, DOWN, and SELECT—these buttons move the selection box (which is on all screens except full screen video) around the screen. The SELECT (or GO) button chooses the item in the selection box.

The front panel also contains a blue LED, which, when illuminated, indicates that digital video is being recorded to disk.

1.4.19 IR Receiver

A dual-footprint location is provided for the IR remote control receiver on the board, and provides for either 40- or 56-kHz frequencies.

1.4.20 IR Blaster

A connector is provided on the rear panel of the Mercury enclosure for plugging in an IR "blaster" that could be used to control auxiliary video equipment, such as a VCR.

1.4.21 Smart Card

Two Smart Card receptacles are provided on the front edge of the circuit board and are accessible from the front panel:

- Conditional Access Smart Card—this card is normally inserted into the slot in the front panel and not removed thereafter. It contains the keys that allow a user to decode and watch encrypted programs.
- WebTV Smart Card—this card can be used for a variety of purposes, such as e-commerce transactions, accessing particular Web sites, or for email access from another user's Mercury system

The Smart Cards must be inserted with the contacts facing down. The Smart Card interfaces are electrically, mechanically, and functionally compliant with the EMV '96 Specification (Europay/MasterCard/Visa). The interfaces are also compliant with the ISO-7816 specification, except that the VPP programming voltage pin is not supported for the WebTV Smart Card but is connected to VCC for the Conditional Access Smart Card. The interfaces support both asynchronous Smart Cards and the I^2C/EEPROM synchronous memory Smart Cards.

1.4.22 IDE Hard Disk

A 40-pin connector provides a means for connecting an IDE hard disk drive to the main board. A separate 4-pin connector for drive power is also provided.